

SIMULATION OF OPTICAL SKIN LESION IMAGES

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Abstract - Black-white and colour skin/lesion images are synthesised with known characteristics such as boundary, skin pattern and colour. The skin and lesion textures are modelled by the auto-regressive (AR) process. Black-white skin lesion images are obtained by combining black-white skin and lesion textures under control of known lesion shape and colour skin lesion images are generated by mixing the coloured skin and lesion textures. Artefact images of skin hair and specular reflection are then added. The synthesised images provide the image set for evaluating image processing algorithms.

Key words - image synthesis, skin lesion, texture, colour

I. INTRODUCTION

In the development of optical skin image processing systems many real skin/lesion images are required to test image processing algorithms. However it is difficult to assess the processing algorithms as the features of real images are unknown or not known precisely. A good skin/lesion image simulation with known features such as boundary location, skin pattern and lesion colour enables rapid assessment of feature estimation algorithms. Simulated skin/lesion images have been used to evaluate image segmentation methods [1] but they are simply produced by overlapping ellipses of varying colours and textures and have no transition area between skin and lesion. Skin/lesion images have been synthesised to compare edge detectors [2]. However these images have not been created from measurement of real lesion images and no information on skin pattern and colour has been exploited. In this paper methods for simulating black-white and colour optical skin/lesion image are investigated. They include lesion shape generation, skin/lesion texture creation, black-white skin/lesion image synthesis, colour skin/lesion image synthesis - including the possibility of adding a simulated area of inflammation surrounding the lesion, and the addition of hair and specular reflection artefacts.

II. LESION SHAPE GENERATION

Firstly, a binary image having a lesion-like shape was generated in three steps: primary shape generation followed by the addition of large-scale irregularity and then small-scale irregularity. The primary shape is shown Fig. 1(a). It is an ellipse with axis ratio and major axis orientation as operator inputs. In order to add large-scale irregularity the ellipse boundary was sampled at 8 uniformly spaced angles from the ellipse centroid. These sampled points were displaced radially by a Gaussian distributed random distance. Then the full boundary was restored by interpolation assuming a linear relationship between radius and angle. The lesion shape after addition of the large-scale irregularity is shown in Fig. 1(b).

To add small scale irregularity each point on the boundary was then displaced in the horizontal and vertical directions by Gaussian distributed random distances to produce the final simulated lesion shape shown in Fig. 1(c). The standard deviations of all three random displacements were under operator control.

In real skin images the boundary between lesion and skin is usually indistinct making the segmentation of skin image difficult. In order to simulate the transition between lesion and skin, a 2D first-order low-pass filter, with operator determined cut-off frequency, was applied to smooth the boundary of binary image. An example of a simulated lesion image with transition is shown in Fig. 1(d).

III. TEXTURE AND SKIN PATTERN SIMULATION

The simulated skin/lesion image needs to incorporate the textures of skin and lesion. Many methods such as Markov models, auto-correlation and histogram models, fractal models, spectral models and linear auto-regressive (AR) models have been proposed for texture synthesis [3]. The linear AR model is judged to give the best visual performance with a reasonably sized parameter space and is adopted.

In the AR model method the texture intensity of a pixel is estimated from a combination of the intensities of pixels in its neighbourhood. It may be regarded as a 2D filter with a 2D noise input. In order to generate a series of random images having the same statistical characteristics of a given image the filter characteristics (AR coefficients) are determined from the given image and the output images are generated using a Gaussian noise input to the filter.

Assume a $N \times N$ discrete texture image. The texture intensity $y(i, j)$ $1 \leq i, j \leq N$ is represented by

$$y(i, j) = \sum_{(m,n) \in D} \alpha(m, n) y(i-m, j-n) + \sigma_w w(i, j) + \mu_w \quad (1)$$

where $w(i, j)$ is a Gaussian white noise with zero mean and unit variance, μ_w and σ_w^2 are the mean and variance of texture noise and D is the neighbourhood set of the AR model. In this study D is chosen shown in Fig. 2. It is causal so that each pixel can be produced by the already synthesised pixels from left to right and from top to bottom. By use of the least square criterion the AR coefficient vector α (a 12×1 vector formed in the numerical order shown in Fig. 2) is estimated by [4]:

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$$\alpha = \left[\sum_{i=3}^N \sum_{j=3}^{N-2} n_d(i, j) n_d^T(i, j) \right]^{-1} \left[\sum_{i=3}^N \sum_{j=3}^{N-2} y_i(i, j) n_d(i, j) \right] \quad (2)$$

where $n_d(i, j)$ is a texture intensity vector formed in the order as shown in Fig. 2 and $y_i(i, j)$ is the given source image. The noise mean μ_w and variance σ_w^2 are calculated by

$$\mu_w = \frac{1}{(N-3)(N-5)} \sum_{i=3}^N \sum_{j=3}^{N-2} r(i, j) \quad (3)$$

$$\sigma_w^2 = \frac{1}{(N-3)(N-5)-1} \sum_{i=3}^N \sum_{j=3}^{N-2} [r(i, j) - \mu_w]^2 \quad (4)$$

where $r(i, j)$ is the residual error image defined as:

$$r(i, j) = y_i(i, j) - n_d^T(i, j) \alpha. \quad (5)$$

The noise mean and the noise variance indicate the closeness of the AR model to the original texture.

After the AR coefficients, the noise mean and variance are estimated from the source image the required texture image is generated by use of (1). The texture part outside the synthesised texture needs to be initialised with texture mean. The synthesised texture is unlimited during texture generation, but is finally limited to a range from 0 to 255.

Since the AR model presumes a random image it does not preserve the quasi-regular skin line pattern and so for the skin image the model was used to simulate the underlying skin texture and the skin pattern was generated separately. The starting point for the skin pattern is a set i of parallel horizontal lines each with an intensity variation across the line given by a Hanning function, width w , amplitude I_i . The spacing of the lines is a random variable (d_s) as is the inter-line intensity variation β_i . The line orientation is randomly altered by shifting the end of each line vertically by random distance d_l with respect to the start of the line. The line is then segmented into lines of random length l_i , the intensity at each segment junction varied by random factor β_2 and linear interpolation of intensity applied along the length of each segment. The orientation is changed in a random fashion from segment to segment by shifting the end of each segment vertically by random distance d_2 with respect to the beginning of the segment. Three such sets ($i=1-3$), rotated to be at relative mean orientations spaced at 120° , are summed to give the final skin pattern. The width of the lines and the means and standard deviations of all the random variables may be set by the operator. Note that the intensity at the start of each segment is given by $I_i \beta_1 \beta_2$.

The process of generating a simulated skin image is then as follows. Remove the skin pattern from a skin image by low-pass filtering as described in [5]. Use this image as a source for the AR model to generate a simulated underlying texture image. Add a skin pattern generated as described above.

As an example, the two 256×256 images of skin and lesion shown in Fig. 3 (a) and (b), respectively were used as source images for setting filter characteristics for the AR models. Then AR model was applied to estimate parameters of the two textures. Their noise means are -7.96×10^{-4} and 0.10 and noise variances are 4.51 and 7.36 respectively. These small noise parameters indicate the degree of visual similarity between the synthesised and original textures. A skin line pattern was simulated as described with line sets at mean orientations of 0° , 120° and 240° and one set having a dominant intensity. The values of the random variables specifying the pattern ($w = 3$, $d_s = 10 \pm 1$, $d_l = 1 \pm 2$, $d_2 = 3 \pm 5$, $l_1 = 20 \pm 5$, $I_{1,2,3} = 10.0, 1.0, 1.0$, $\beta_i = 2 \pm 0.5$, $\beta_2 = 1 \pm 0.3$; all distances in pixels) were chosen to give a typical resultant pattern. The synthesised textures with skin line pattern for skin and lesion are shown in Fig. 4 (a) and (b), respectively.

IV. BLACK-WHITE SKIN/LESION IMAGE

In order to generate the black-white simulated skin/lesion image, the lesion shape with the boundary transition, the skin and lesion textures with skin pattern need to be combined. The lesion shape image controls the mixing of the skin and lesion textures. The combined skin/lesion image $z(i, j)$ is determined by

$$z(i, j) = \frac{x(i, j)}{255} y_1(i, j) + \left[1 - \frac{x(i, j)}{255} \right] y_2(i, j) \quad (6)$$

where $y_1(i, j)$ and $y_2(i, j)$ denote the textures of skin and lesion and $x(i, j)$ is the lesion shape image. Their intensities have a range from 0 to 255. As an example, the lesion shape image Fig. 1 (d), the skin texture Fig. 4 (a) and the lesion texture Fig. 4 (b) were combined by use of (6). The resulting skin/lesion image is shown in Fig. 5.

V. COLOUR SKIN/LESION IMAGE

Colour skin/lesion images are created by pseudo colour processing [6]. Since skin and lesion have different colours, the skin colour and lesion images need to be produced separately. Then they are combined under the control of lesion shape image with the relation

$$z_c(i, j, k) = \frac{x(i, j)}{255} y_{1c}(i, j, k) + \left[1 - \frac{x(i, j)}{255} \right] y_{2c}(i, j, k) \quad (7)$$

where $k=1, 2, 3$ is the colour-space variable, $y_{1c}(i, j, k)$ and $y_{2c}(i, j, k)$ denote the pseudo colour images of skin and lesion and $z_c(i, j, k)$ is the pseudo colour skin/lesion image. These images can be defined in various colour spaces such as RGB, LUV and HSV. This combination allows varying colour and skin pattern across the lesion.

In the simulation the pseudo colour processing was conducted by Matlab software. The colour skin texture image was produced by assigning the RGB colour look-up table from [0.5, 0.4, 0.35] to [1., 0.8, 0.7] with 64 equal-spaced increments. Similarly the pseudo colour processing of lesion texture image was performed with a RGB look-up table vary-

ing from [0.275, 0.2, 0.2] to [0.715, 0.52, 0.52]. The combined colour skin/lesion image is given in Fig. 6.

The inflammation area surrounding some lesions is a good indicator for skin cancer diagnosis. It is simulated in two steps. Firstly, a boundary is generated. From the lesion centre the lesion boundary is sampled at 64 points spaced equally in aspect angle and 64 radii are constructed by connecting the centre with each sampled point. The 64 radii are extended by a random distance and the boundary of the inflamed area is determined by connecting the points of the extended radii. Secondly, the red component of pixel value in the inflamed area is increased by an operator-set value. A colour lesion image with inflamed area is shown in Fig. 7.

VI. HAIR ON SKIN IMAGE

Hair on a skin image is an obvious problem for image processing. In order to investigate the effect of hair and hair removal on skin line pattern, hairs with known shape and location on skin image may be simulated by simply adding hair-like lines to the image. A black curved hair of length 100 pixels and width 3 pixels is shown in Fig. 6.

VII. SPECULAR REFLECTION

Specular reflection usually results in the bright spots in optical skin images. It may be simulated by applying spike noises to image pixels distributed uniformly. Fig.8 gives the skin image with specular reflection.

VIII. CONCLUSIONS

The synthesis of black-white and colour optical skin images has been studied. The lesion shape image is generated by an ellipse with large-scale and small-scale irregularity. A low-pass filter is used to smooth the lesion boundary. The textures of skin and lesion are created with the AR models and a simulated skin pattern is added. The black-white skin/lesion image is produced by mixing the skin and lesion textures under the control of the lesion shape image.

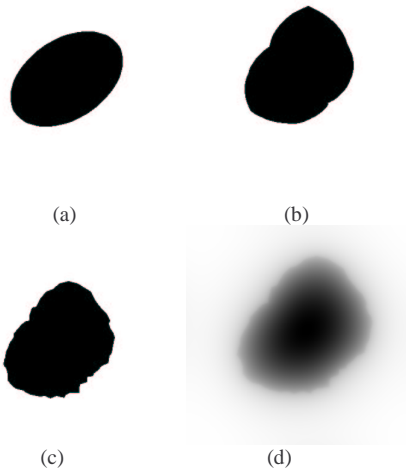


Fig. 1 The simulated lesion shapes. Image size 256x256; ellipse axes 150:100; major axis elevation 50°; polar random shift 2±0.5; Cartesian random shift 0±0.5; smoothing filter first order, cut-off 0.0156.

The colour textures of skin and lesion are obtained by different pseudo colour processing. The colour skin/lesion image is generated by combining the colour skin and lesion textures in proportion to the pixel value of the lesion shape image. Simulations of hair and specular reflection on skin image are also conducted. The synthesised black-white and colour skin/lesion images have a varying pattern across the lesion and an inflammation area surrounding lesion is simulated for the colour skin/lesion image. They can be used for image pre-processing, lesion boundary detection, colour image segmentation and skin line analysis to detect skin cancer.

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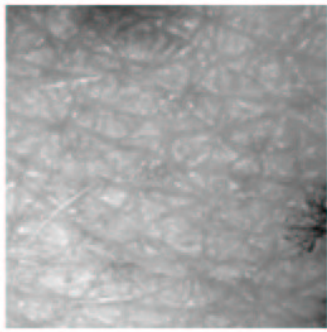
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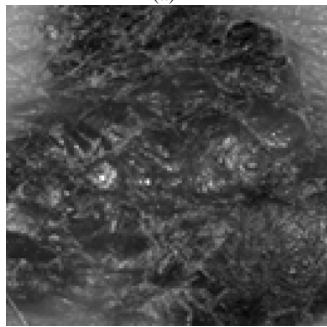
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	7	8	9	10	11	
	6	2	3	4	12	
	5	1	(x,y)			

Fig. 2 Neighbour set of AR model for pixel (x,y)

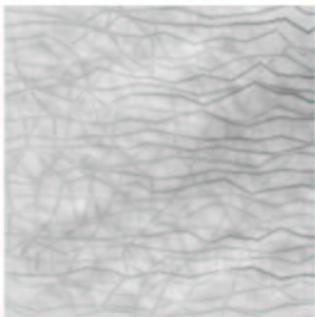


(a)

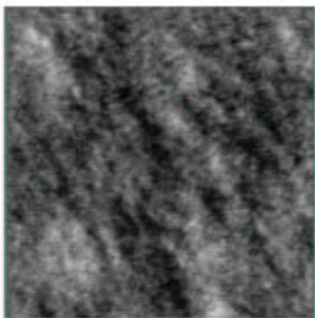


(b)

Fig. 3 Skin and lesion texture images



(a)



(b)

Fig. 4 Synthesised skin and lesion texture images

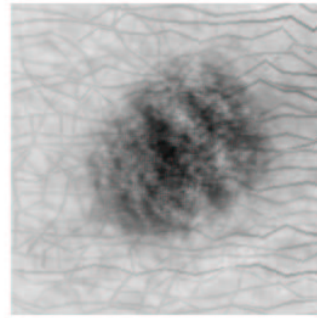


Fig. 5 Simulated black-white skin/lesion image

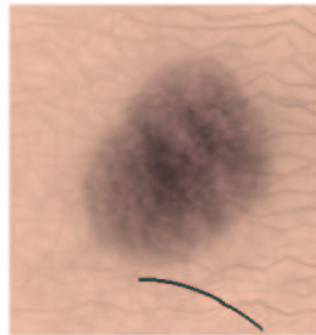


Fig. 6 Simulated colour skin/lesion image with hair

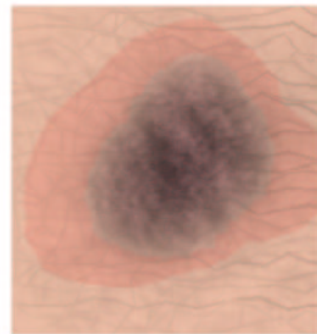


Fig. 7 Colour skin/lesion image with inflamed area

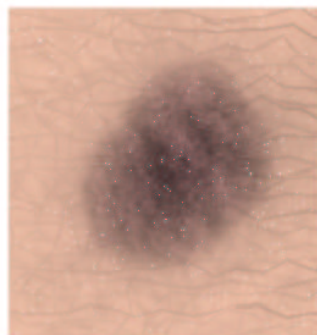


Fig.8 Simulated specular reflection on skin image